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Hello everyone, I’m Ziqing Yu, today I’ll present my Bachelor thesis to you, the title is Understanding the positive trend in total water storage of OB basin using space born observation. And it was supervised by Dr Tourian and Mr Saemian

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First, we will have a brief introduction of some basic ideas, then we will talk about the motivation and the study area. After that, I’ll introduce the data we’ve used in this work and the methods as well. At last, I’m going to show the results, the conclusion and outlook.

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Now we are talking about water, as we understand it, water is a necessary ingredient of life. This is a picture of earth, we call it a blue planet, 71% of its surface are water, everything blue in this picture is water, and all things white here are water as well. About 98% of water is in the oceans, 1.6% is in ice caps, only 0.4% is stored on land, most of them is ground water. So, a very small change on the water cycle can cause a big effect on how water delivers into the continent and water resources.

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The Total Water Storage (TWS) is the sum of all above and below surface water storages, including canopy water, rivers and lakes, soil moisture and groundwater, and it represents a synthetic proxy of the dynamic of slow-responding hydrological quantities.

Water is not static at all, it is very dynamic, it evaporates and transpirates from the surface, it moves over land, it rains down as precipitation, this can be simplified as this equation: the deviation of total water storage is equal to precipitation minus evapotranspiration minus run off in an area. We are always trying to close this budget.

However, even though this equation looks very easy, hydrology is very hard. There is not many observations globally, the water changes so fast in space and time, in some ways, the remote sensing is a perfect way to do it. Using satellite, we can observe it globally in a long term. One mission of them is GRACE

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The GRACE mission is a joint partnership between (NASA) in the United States and (DLR) in Germany. It makes an measurement of earth’s gravity field, which are caused by monthly changes in mass. Unlike normal remote sensing satellite, there are two identical satellites in in the same orbital plane at an approximate distance. The distance between these 2 satellites are not identical because of the earth mass change and by measuring that, the mass changes can be detected. The mass changes can be thought of as concentrated in a very thin layer of water thickness changes near the Earth’s surface by moving ocean, atmospheric and land ice masses and by mass exchanges between these Earth system compartments. The GRACE mission ended in October 2017. GRACE FO launched as followers launched in May 2018. Which means there is a gap about one year in the data we have.

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This is a figure from a paper in nature, as we can see in this figure, since the launch of GRACE, the water storage in many areas have changed, the blue area in this figure has gain water from other places, like western Zambezi basin in Africa or Northern Great Plains in north America. Ob river basin is also one of them.

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This is the water storage change from Jan 2003 to Dec 2019 from the mascon solution (解释 mascon) of CSR Release 06, if we make a linear regression here we are able to see that the water behavior of total water storage have different tendency in since the launch of GRACE:

The negative trend of this line might happen in this short port between 2010 and 2012.

(introduce the 4 periods)

We are interested to see the reasons behind it.

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We are talking about Ob river basin. What is it, what’s the specialty?

Ob River is a river of central Russia in West Siberia, and it is one of the greatest river of Asia, it’s about 3600 kilometer long, the basin area covers about 3 million quad kilometer, and 85% of lay in west Siberian plain.

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According to Köppen Gerger climate classification, major part of this basin, major part of this basin belongs to subarctic climate, it has a short warm summer and long cold winter. The rainfall occurs mainly in summer.

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So as mentioned, we use GRACE to determine the total water storage, there are several centers who provides level 2 GRACE and GRACE-FO data. We’ve used solutions from JPL, CSR, GFZ and ITSG. Using the EWH bundle developed by institute, we can calculate the equivalent water height, which represent the total water storage from these level-2 data.

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For precipitation and evapotranspiration, there are a lot of datasets, they use models to represent these phenomena based on the in-situ gauge measurement. The properties of them are of course not identical. These 2 tables show the datasets we used in this work. All of them can provide the data in last 2 decades which are we need. This shows the timespan, the temporal and spatial resolutions and spatial coverage(有一个60N？)

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For Runoff we have the models as well. A tricky thing is that we also have the runoff in-situ data collected in Salekhard in Russia from GRDC. But this in-situ data only exist till 2010.

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If we compare these models with in-situ, for example, by calculating the RMSE, we can see the errors are quite big, and even if the we see the best model ERA5, there is a lag between this model and in-situ.

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We may think, we have this equation, right? This terrestrial water balance, R is equal to P-et

-dS/dt. But there is paper, which shows, this is not a good way to do that. These are some cut from the paper, it uses 3 metrics to do the estimate: percentage bias, correlation and the Nash-Sutcliffe efficiency which summers these 2 issues. For percentage bias we need it less than 25% to say, ok this is a good estimate but we can see we hardly reaches this standard. For some areas like amazon, the result looks good. bur for most area and especially for Ob, this estimation is not ideal. (make it better)

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Fortunately, there is another way to calculate the discharge. We can use the satellite altimetry to do that from the water level. We’ll talk about the methods later. Now I’m showing the satellite missions we’ve considered. They are Envisat (Environmental Satellite), from 6.2006 to 10 2010, SARAL (**S**atellite with **AR**gos and **AL**tiKa) from 2013 to 2016 and Sentinel-3 since 2016. (others path is too far from the station), Then We can use the altbundle developed by the institute to get the water level data.

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So we have 4 timeseries for total water storage with uncertainties, we can use the Gauss Markov adjustment to merge these four time series into one, this equations shows how to do it for one month, of course we don’t need to do that month by month, instead we can build a large matrix to do it for all months in one time, this shows the basic ideas. And we can also do this for our precipitation and evapotranspiration, the problem is, we don’t have the uncertainties for these two components. We do it that way, we assume the precipitation or evapotranspiration in the same month, January, follows the normal contribution, then we calculate the unbias standard deviation and use it as the uncertainty for this month for each dataset.

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And for total water storage we need the trend for it, so we use the center deviation since we have the monthly TWS. To find the changing point, we used the moving average. Its 12 here because we have 12 months in a year and then we search the abrupt change in the mean value in moving average series. These 2 steps can be down using MATLAB function movmean and ischange. (more details here)

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Now it’s the method provide by this paper to calculate the runoff from water level. We have 2 time series one is in-situ runoff, another one is water level from satellite altimetry for example from Envisat. The time spans are not identical because that’s no necessary. Then we get the cumulative distribution function for each of them, at last, we can find the relationship between them and plot a rating curve, (update the last figure)

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We’ve chosen several virtual stations to observe the water level, for each satellite mission, in order to get the better approach, we choose the time series, whose virtual station is near the Salekhard, where the in-situ runoff is measured. They are blue line for Envisat, the blue line for SARAL and red line here for Sentinel

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Now we can have our results,

The picture above is TWSA from 4 datacenters from SH methods and from CSR mascon. The below one is the timeseries after merging 4, well, those 4 except mascon solution.

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Trend of TWSA. Moving average and the changing point detected, we found 2 points near 2012 and 2016.

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This is the spatial behavior of this basin using mascon CSR RL06, it has decrease in the first period, this reduction in west part

Second period, the basin gained a lot water from the outside, especially in north and west

Third period lost water, it occurs same as the second, but also in south east.

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Before we see time series of precipitation, we got this figure. The spatial pattens of precipitation of June of 2003 from different dataset are shown, they follow each other fairly well

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For all datasets above

After merging them into one (below)

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We do the same for evapotranspiration, SSEBO shows a bit different from other in west south.

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And same

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This is the runoff generated from water level, at first there were some gaps, those were filled with interpolation.

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Then we can calculate the mean value with uncertainties for each of these components in the 3 periods split by 2 changing points. These numbers are the mean value of them in each period. We will discuss them later on in a table.

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The first 4 rows are same as we see in the diagrams before

We can judge the quality of them. the statement of terrestrial water balance p-et-r-ds/dt should equal to 0. If we take the first period as a baseline, the results are acceptable.

Now we can discuss about the water change regarding all the values in this table. Still, we take the first period as the baseline, we see the major part of the precipitation goes to evapotranspiration, 35.59 of 39.12, is nearly 80%. In second period, the precipitation has increased by 5,2, but the evapotranspiration has increased only 1,53, which is only 30% of the gained precipitation. And it is hard to say that the if runoff has changed in this period. This means in this period from 2013 to 2015, the amount of precipitation grew sharply and most of them remain as total water storage in this area.

The things have changed, however after 2015. The precipitation has decreased compared to the second period by 2,15, more than half of it leads to evapotranspiration, well, the evapotranspiration is stronger comparing to the second period. The runoff may also increase, though we are not 100% sure because of the high uncertainty, As a result of these, the area lost water in this period. (更多讨论关于)

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And then we can make a conclusion. From ... to ... the total

In the future, we can do more spatial analyze of the basin, since the area is quite big and we have already seen before that the water behavior in the east and the west part are quite different,

Besides, we may also interest in what has happened for those increased or lost water storage, die they go to the groundwater or permafrost or maybe other form? This can be explained in the future work.